403

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SEASONAL HISTORY STUDIES OF

DENDROCTONUS BREVICOMIS

LEC.,

IN TWO AREAS IN CALIFORNIA

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CONTENTS

SEASONAL HISTORY STUDIES OF DENDROCTONUS BREVICOMIS LEC., IN TWO AREAS IN CALIFORNIA.

INTRODUCTION

As a result of studies carried on during the past season a considerable additional information is available concerning the seasonal history of the western pine beetle in two widely separated areas in California, namely the Sierra National Forest and the Modoc National Forest. The information in this report presents the seasonal development of this insect as it occurs in the two outstanding types of ponderosa pine designated as the "east side" and " west side" types.

The Modoc N. F. is part of a region that varies considerably climatically from that represented by the Sierra N. F. The Modoc is representative of the "east side" type of California and is characterized by relatively severe winters and short growing seasons, while the Sierra is characteristic of the "west side" type with mild winters and long growing seasons. For this reason it is of considerable interest to point out the differences in development in the two areas during the same season, as well as the differences in the same area in successive seasons.

Three main points are covered in the present report: (1) a comparison of the pine beetle generations in 1932 with those in 1933 on the Sierra N.F., (2) a comparison of pine beetle generations in 1933 on the Sierra N.F. with those of 1933 on the Modoc N.F. and (3) a detailed discussion of the development of infestation on the Modoc N.F. during the summer of 1933.

I wish at this time to express appreciation to Dr. K. A. Salman for aid in outlining and carrying on the Modoc Study; to Mr. G. R. Struble for carrying on the Sierra observations in 1933; to Mr. [illegible] Johnson for aid in drafting graphs and to Mr. J. M. Miller for valuable guidance in the presentation of data.

HISTORY OF PREVIOUS WORK

In 1926 Person sampled a series of brood trees at Cascadel on the Sierra throughout the summer and by averaging his data found that three generations were completed that year. In 1932 in the same region Furniss made a similar study by means of sampling both standing and felled brood trees throughout the season. The long favorable growing season from early spring until late fall allowed four generations of pine beetles to develope in some trees. However, most of the beetles were able to produce only three complete generations. The Sierra records were continued during the season of 1933.

In 1928 Person made a preliminary life history study in the Modoc N.F. by sampling representative brood trees and found that most of the beetles completed two generations while a small portion was able to establish a partial third generation. In 1930 in connection with biological control studies of the pine beetle in this region it was evident that there were two main generations during the summer. Due to the advent of cold weather early in the fall apparently there was no partial third generation. Subsequent to the low temperature conditions in Northern California during the winter of 1932-33, a continuous set of records was made of pine beetle development during the season of 1933 on the Modoc N.F. This study was for the purpose of following the development of infestation in a season following severe reduction of pine beetle population.

METHODS USED IN 1932-33 STUDIES

Sierra National Forest, Bass Lake Region:

During the early part of April 1932 a number of brood trees were sampled to determine the condition of the brood. From that time until the winter of 1933-34 a series of different brood trees was observed in order to follow the development of the pine beetle from generation to generation. In this manner the number of average length generations was calculated over a period of two years.

During the season of 1933 five tree cages were erected on overwintering a first seasonal brood trees in order to obtain the duration, peak, and total amount of emergence. These tree cages supplemented the sampling of brood trees to a considerable extent.

Modoc National Forest, Hackamore Region:

No life history observations were made in this area in 1932. From the last of March 1933 until the winter of 33-34 continuous observations were made on a series of brood trees. As contrasted with the Sierra observations, the Modoc study has been made almost exclusively by means of tree cages and supplemented only to a limited extent by sampling. The regional survey, conducted throughout the summer by the ECW organization, aided in the selection of brood trees that were representative of the different seasonal generations. Tree cages were erected on the chosen trees and regular collections were made of the emerging pine beetle adults.

BROOD DEVELOPMENT ON THE SIERRA N.F., 1932

Overwintering Generation 1931-32:

In the spring of 1932 when activity began the overwintering brood was predominantly in the large larval stage. First pupal development must have taken place near the middle of March or earlier although no exact information on this point is available. When the initial observations were made during the first part of April, pupal development was at its height and the formation of new adults was taking place. Emergence of new adults occurred during the latter part of April and the first part of May.

First Seasonal Generation, 1932:

The attack of the first seasonal generation was well established by the last part of May at which time rainy, rather cold weather set in. This did not result in any considerable lengthening of the brood period because of the fact that the beetles were well established by that time. Temperatures were not so low but that brood development continued at almost its normal rate. The first seasonal generation was completed and emergence took place during the last part of June and the first part of July.- see Graph (1).

Second Seasonal Generation, 1932:

The mid-summer or second seasonal generation developed during a period of optimum temperatures for the species so development was very rapid. Emergence occurred during August. The short period of development during this generation is illustrated in Graph (1).

Third Seasonal Generation, 1932:

The third seasonal generation was initiated during August and the first part of September and in the main furnished the generation which overwintered in the large larval stage. The brood in the very earliest of the third generation trees was able to complete its development and emerge during October and November to furnish the basis for a partial fourth generation.

The fact that most of the third generation passed part of September and all of October ~~xxxxx~~ and November in the large larval stage while other stages were in the process of development is sufficiently outstanding to be worthy of comment. Apparently prepupal larvae have a considerably higher temperature requirement for transformation than do the other stages of this insect. This condition causes the large larvae to cease development comparatively early in the fall. Graph (1), season of 1932, illustrates this point.

When pupae are developed in the fall, they transform into new adults before cold weather. It is a characteristic of the western pine beetle that the pupae do not overwinter.

Fourth Seasonal Generation, 1932:

A small portion of the third generation emerged and established a partial fourth generation. This partial fourth generation overwintered in the egg and very small larval stages.

BROOD DEVELOPMENT ON THE SIERRA N.F., 1933

Overwintering Generation, 1932-33:

The overwintering generation was composed of part of the third and all of the fourth seasonal generation of 1932. Brood development

started very early with the formation of pupae during the first part of March. This was followed in a short time by the formation of new adults and emergence. Soon after the emergence had begun a cold rainy period of nearly a month and a half delayed emergence of the remainder of the brood so that it was not completed until well into June. - see Graph (1). This is the latest emergence of an overwintering generation that has ever been recorded in the Bass Lake area.

First Seasonal Generation, 1933:

The early attacks of the first generation are separated from the main attacks by a period of over a month during which time no emergence took place due to cold rainy weather. The main portion of the first generation was established during the latter part of May and the first part of June. This "stringing out" of attacks caused an abnormally long first generation and had the effect of a similar prolongation of the following seasonal generations. Emergence of the first generation occurred during June, July and the first part of August.

Second Seasonal Generation, 1933:

Attacks of the second generation covered the period from the last of June to the middle of August. This generation which would ordinarily be a short midsummer one was so delayed that cool fall weather set in before development was completed. Emergence extended from the middle of August to the last of October.

Third Seasonal Generation, 1933:

Attacks occurred during September, October and November. Large larvae developed which will emerge during the spring of 1934, thus rounding out three full generational

COMPARISON OF BROOD DEVELOPMENT ON THE SIERRA N. F. IN 1932 AND 1933

Graph (1) presents graphically a comparison of brood development during 1932 and 1933 on the Sierra N.F. In 1932 there were three complete generations and a partial fourth as contrasted with three complete generations in 1933. The difference must be attributed to climatic variation within the two seasons. A comparison of the relative length of the developmental period in the two seasons shows them to be about equal. The only apparent difference was in the cold period which followed the early warm temperatures. This happened during the spring of both years and is characteristic for the region. In 1932 the cold weather was sufficiently delayed for the first seasonal generation to become fully established. In 1933 the cold weather stopped the emergence of the overwintering generation before it had fairly begun and emergence did not begin again until over a month later. This difference of one month is apparent throughout the season.

BROOD DEVELOPMENT ON THE MODOC N.F., 1933

Overwintering Generation, 1933:

In connection with the caging of overwintering brood trees during the spring of 1933, twelve of these trees were sampled at one week intervals from the middle of April until emergence began in the cages in June. In this manner the very earliest development was followed. Formation of the first pupae took place on about the 20th of April, reached its height the last week of May and continued on into June. Formation of the first new adults took place about the 20th of May.

Emergence of the overwintering generation began near the first of June and peak of emergence was reached by the middle of June. Then followed a gradual tapering off until the 24th of July when emergence of this generation finally ceased. Emergence from twelce tree cages placed on as many overwintering brood trees furnished the basis for these observations.

First Seasonal Generation, 1933:

Attack of the first seasonal generation occurred between the first of June and the first of August. Emergence denoting the completion of the first seasonal generation began near the first of August, reached its peak by the middle of August and declined until the 18th of September when emergence ceased. The emergence in six tree cages on selected brood trees of the first summer generation served to delineate the first seasonal generation.

Second Seasonal Generation, 1933:

Attack of the second seasonal generation started the first of August and ended near the middle of October. A partial emergence from the second seasonal generation began near the middle of September and continued quite intermittently until the middle of November, after which time there was no further emergence before cold weather. This late emergence established a partial third generation. By far the greater portion of the second generation overwintered in the large larval stage and thus on the average two generations prevailed in the Modoc N.F. during 1933,- see Graph (2). Six tree cages on as many second generation trees yielded the data on the second generation.

Third Seasonal Generation, 1933:

A relatively small partial third generation was established during the month of October and the first part of November, by emergence of "split brood" trees of the second generation. The third generation constituting about ten percent of the total infestation overwintered in the egg and very small larval stages.

COMPARISON OF BROOD DEVELOPMENT IN 1933 ON THE SIERRA N.F. AND MODOC N.F.

The above constitutes the development of generations as shown by

emergence from selected caged trees on the Modoc N.F. Graph (2) contrasts the seasonal development of the pine beetle on the Sierra N.F. and the Modoc N.F. The Sierra was characterized by three complete generations, while two generations and a small part of third represented the Modoc conditions. Contrasting the two over a series of years it is evident, from life history studies during three different years in each area, that the usual condition on the Sierra is three complete generations and occasionally a partial fourth. On the Modoc the normal condition is two complete generations and occasionally a partial third. This should furnish an empirical means for determining the number of generations in these two regions during any given year in the future.

DEVELOPMENTS DURING THE WINTER PERIOD
(Explanation of Graphs 1 and 2)

It will be noted that in the life history Graph (1) of this study the overwintering brood is represented as being in the large larval stage in the spring of the year in which it completes development. This is despite the fact that all stages except pupae are shown to enter the winter. Large larvae predominate. Any new adults that have been formed in the late fall tend to emerge during warm periods before spring so that for the most part they are lost and do not enter into the establishment of the new brood. The egg stage is an inconsiderable portion of the total brood and need hardly be considered in the establishment of the first seasonal generation. Concerning the small larval stage, it was noticed during the spring of 1933 and 1934 at Bass Lake on the Sierra N.F. that this stage tends to "catch up" in development with the large larvae by the time that extensive activity begins in the spring. Therefore, we can to all practical purposes consider that the pine beetle in this area passes the winter in the large larval stage which is responsible for the establishment of the first seasonal generation in the spring.

Mr. F. P. Keen in correspondence indicates that this "catching up" of the small larvae is much less prevalent in the pine stands of Oregon, stating that fully 17 percent of the overwintering population in 1932 was made up of small larvae. The same condition was found to be the case in the Modoc N.F. of California during the winter of 1932-33. This is probably accounted for by the fact that in Oregon and in Northern California the winters are fairly severe so that from the time development ceases in the fall until activity begins in the spring, there are no open periods in which development of small larvae can take place.

Graph (2) shows that the overwintering generation in both regions was in the large larval stage by the time that development started in the spring. This condition is due to a different reason in each case. Probably in both regions the percent of small larvae was about the same when development ceased in the fall. In the Sierra the predominance of large larvae in the spring may be attributed to the tendency of the small larvae to "catch up" with the large larvae during the course of the winter and early spring. In the Modoc during the winter of 1932-33 the extremely low temperature conditions caused the death of practically all small larvae either directly or indirectly, which resulted in the preponderance of the large larval stage in the spring of 1933. In this connection, a study should be made of normal overwintering mortality of young larvae to contrast with that in seasons following winters of abnormally low temperature conditions.

CAGE EXPERIMENT, MODOC N.F., 1933

Description of Cage:

During the early spring of 1933 a 32 inch DBH, five log, class 4C, ponderosa pine was chosen upon which to force pine beetle attacks. A large quantity of brood bark had been placed in metal rearing cans for the purpose of making emergence counts of the overwintering generation and the emerging beetles from this bark were used to force the attack. A funnel type screen cage nineteen feet long and three feet wide was placed on the south side of the selected tree. Figure (1) illustrates the cage in place. Observations on this cage form a portion of the basic data from which the life history chart (1) was constructed. A large introduction cage shown in figure 1 will be designated as (A) and a small cage which was later erected on the opposite side of the tree as (B).

Introduction of Adult Pine Beetles:

The first pine beetles were placed in Cage (A) on June 2nd and the last on June 21st, during which period a total of 4,170 beetles were introduced. At first all of the beetles were placed in the cage near the bottom. However, it was found that when this was done the beetles attacked only to a height of about eight feet above the point of introduction. Accordingly from June 16th on the beetles were placed in the cage twelve feet above the base. In this manner a good uniform attack was obtained. Those beetles which were injured or were unable for some reason to establish themselves fell into the collection jar at the bottom of the cage where they were removed and counted. The dead beetles had been removed, leaving a total of 2571 supposedly healthy beetles which had established themselves in the tree. From this the density of attacks was calculated at between 15 and 18 square foot or near the mean of natural attack.

Establishment of Attack:

By June 8th successful attacks exhibiting dry frass were noted inside the cage. By June 11th the attack inside the cage was well established. On June 11th adult pine beetles were noted on the outside of the cage attracted to the tree by the activity of the attacking beetles within the cage. By June 23rd a heavy attack of D. brevicomis was present on the opposite of the tree from the caged area. Adults continued to be attracted to the tree in decreasing numbers until the first days of July.

Reemergence of Parent Adults:

From the 28th of June until the 11th of July no more beetles fell down into the collection jar. On July 11th living adults, which must be considered as being reemerged parent adults, were collected from the jar at the bottom of the cage. From this date until August 3rd parent adults continued to reemerge until a total of 1377 or 53.6 percent of the attacking beetles had reemerged. This left a total of 1194 or 46.4 percent of the attacking beetles inside the cage, which, after establishing a brood, had perished due to one cause of another. The peak of parent adult reemergence occurred on the 17th of July.

Progeny of the Parent Adults:

From July 17th to July 24th, 430 of the reemerged parent adults taken from cage (A) were removed and introduced into a screen cage containing a three foot log cut from a vigorous ponderosa pine which had been felled on July 16th for this purpose. By July 18th the beetles had attacked the log and by July 19th a vigorous attack had been established. The log containing the reemerged parent adult attacks was examined on August 9th at which time ½ grown larvae were present. The phloem showed a tendency to sour as is usual in attempting to rear *D. brevicomis* from small logs. On September 6th the log was removed to Berkeley where it was again examined on October 21st, at which time the beetles had all emerged. The log was rather exceptional in that a good brood was developed despite the presence of a good deal of mould. However, it was not followed with the idea of observing the development of the brood but rather to see if the reemerged parent adults could establish another brood. This they were able to do so. The attacks seemed to be normal and the amount of established brood about the same as that initiated by new adults.

Progeny from the Original Attack:

Sometime between the 3rd and the 9th of August the progeny from the original attack in cage (A) began to emerge. It will be noted that the emergence of the progeny began very soon after the cessation of reemergence of the parent adults. Progeny continued to emerge in the cage until the middle of October. Height of emergence was reached on August 21st although emergence was abundant from the 10th of August until the same time in September. A total of 8241 new adults emerged from the 2571 which supposedly were effective in producing attacks. This shows an increase of 3.2 times.

Reemergence of Parent Adults Correlated with Stage of Progeny:

Returning now to July 17th, a small tree cage designated as (B) was erected on the opposite side of the tree from the introduction cage. This cage covered the normal attack of beetles which had been attracted to the tree as a result of forcing attack in the introduction cage. The base of cage (B) was located 9 feet above the surface of the ground and extended five feet up the tree. On the date this cage was erected a sample was taken just below the cage and the brood counted. The brood was found to be in the ½ grown larval stage. The next day reemerged parent adults were taken from the collection jar at the bottom of this cage (B). The reemergence curve for this cage is not complete but seems to coincide very closely with that from the large introduction cage. The brood in cage (B) must have very nearly approximated the condition of the brood in the sample, therefore we may say that reemergence of parent adults takes place from the time that the progeny is in the less than half grown larval stage and continues until about the time that the first new adults begin to emerge. The peak of reemergence occurs about the time that the progeny is in the half grown larval stage.

Comparison of Forced Attack Cage (A) with Normal Attack Cage (B):

Cage (B) represented the caging of a normal attack while cage (A) covered a forced attack starting with a known number of beetles. Emergence

started out at about the same time in both cages. Peak of emergence was attained about one week earlier in cage (B). Final emergence was prolonged a month longer in the introduction cage (A) than was the case in cage (B). This may be explained in two ways; first, the attacks near the top of the introduction cage were delayed in being started due to the method of introduction and, second, the cage extended nearly to the base of the tree where development is known to be slower than higher on the tree.

Basic Data Obtained from the Caging Experiment:

The emergence of new adults from cage (A) and cage (B) coincides with that in the six tree cages upon first generation trees so that events happening on this tree can be transposed into first generation events. Time and amount of parent adult emergence had been used in this manner. In addition the increase of progeny over attacking population as shown by cage (A) has been incorporated in the life history chart. Following is a quantitative summary of events in the large introduction cage.

Summary of Events, Cage (A)

Total number of beetles introduced		4,170
" " " " ineffective in producing attack . .		1,599
" " " " effective " " " . .		2,571
" " " reemerged adults		1,377
Percent of attacking beetles which reemerged	53.6	
" " " " not able to reemerge . . .	46.4	
Total progeny produced by the original attacking beetles . .		8,241
Percent of Increase of progeny over attacking beetles . .	220.0	

HYPOTHETICAL BROOD DEVELOPMENT DURING 1933
(As illustrated by Life History Chart)

Overwintering Population:

The development of D. brevicomis in the Modoc during the season of 1933 can best be illustrated by a description of the accompanying life history chart which shows the hypothetical increase of the pine beetle during the summer, starting at a very low ebb in the spring. It has been pointed out that in the fall of 1932 a relatively heavy infestation of the pine beetle started to overwinter. The total population at this particular time has been represented graphically by means of ten infested trees for the sake of convenience. During December, 1932, and February, 1933, low temperatures caused heavy mortality of the pine beetle broods. The percent of mortality has been variously estimated, the most conservative being in the vicinity of 65 percent. However, it was later pointed out that the effectiveness of the freeze probably came nearer to 90 percent. For the purposes of this report, which is to show the possibilities for recovery during a single season following severe reductionof population, the mortality has been chosen arbitrarily at 80 percent. Therefore in May, prior to the first emergence in 1933, the infestation may be illustrated as being the equivalent of two normal brood trees. In the field the condition was that some living beetles were contained in all trees, some containing more than others as has been previously pointed out.

First Seasonal Generation:

For the purposes of illustration it has been taken for granted that the beetles surviving the winter of 1932-33 would emerge and attack a bark area approximately equal to the original infested area or, in this instance two trees, representing the main first seasonal generation. As brought out by the forced attack, Cage (A), about half of the beetles causing the first seasonal attacks would reemerge and attack a bark area equal to half of the original, or one tree which would become a late first generation tree. Thus three brood trees are represented in the first seasonal generation.

Second Seasonal Generation:

The emergence of progeny in the forced attack tree was more than triple the attacking beetles. In the life history chart the progeny is shown to double the attacking beetles in each instance. This increasing of progeny over parents is well known in cases where there is an abundance of food. The Modoc quite evidently was a case in point immediately following the freeze.

The combination of natural increase and reemergence of parent adults caused the three first generation trees to produce eight second generation trees. Reference to the life history chart will best show how this was accomplished. Seven of the second generation trees overwintered in their entirety while the very earliest was partially abandoned to form a partial third generation.

Third Seasonal Generation:

Two trees attacked by the progeny of the very earliest of the second generation trees represent a partial third generation which was established late in the fall and overwintered in the egg stage.

Therefore seven second generation trees with larval brood and two third generation trees containing eggs represent the 1933-34 overwintering generation. Thus a 350 percent increase of infestation took place during the season and 90 percent of the 1930 infestation was established by the winter of 1933 where only 20 percent had been present in the spring.

Seasonal Increase as Shown by Life History Chart:

The life history chart is an attempt to show graphically, from what is known of the habits of the western pine beetle, how it is possible for this insect to increase in a single season following severe reduction in numbers such as was the case following the freeze of 1932-33. In this instance the infestation was shown to have a potential recovery that would very nearly approach the original infestation in a single year, (see life history chart).

Comparison of Hypothetical Increase with Actual Increase:

One interesting relationship can be pointed out at the present time. The relative number of summer and winter trees may be an important index to whether infestation is on the increase or decrease during a given year. Four plots in the Badger area of the Modoc, which were controlled both in 1931 and

in 1933 furnish a good basis for comparison. Table (1) shows the total seasonal loss, the amount treated by winter control and the percent of total loss treated by winter control for each plot for each year. The winter infestation on the four plots in 1931 averaged 46.5 percent of the total infestation while in 1933 it averaged 66.1 percent of the total.

TABLE I.

Showing Relative Amounts of Overwintering Generation in 1931 and 1933

Plot	Percent of Total Loss Treated by Winter Control: 1 9 3 1	1 9 3 3
Test 2	51.1	73.3
" 3	65.2	41.8
[illegible]ck.5	28.9	83.3
[illegible] 5	38.2	74.1
4 plots	46.5	66.1

The life history chart shows four summer generation trees in 1933 and nine overwintering trees. The nine overwintering trees represent 69.2 percent of the total seasonal infestation and very closely approximates the average obtained in summarizing the four plots in Table (1).

DENSITY OF ATTACK AS IT AFFECTS [illegible] AND MORTALITY OF THE BROOD.

One additional feature which parallels somewhat all the others was brought out during the past winter in connection with the winter control project on the Modoc. Unfortunately the observation remains an impression rather than a statement with statistical basis. It has long been recognized that there is a very considerable difference in density of attacks from tree to tree and from season to season. During the winter of 1932 attacks were very heavy and the broods were heavy at the time of the freeze. In contrast the attacks of the overwintering 1933 generation were extremely light. However, the brood seemed to be even heavier than that of 1932. The light attack persisted throughout the summer of 1933. The photograph, Fig. (2), will serve to illustrate the point at hand. The heavy attack illustrates the prevalent type of attack in 1932 with some trees of the medium type and practically no light attacks. In 1933 the reverse was the case, with the light attacks predominant, medium attacks fairly numerous and very few heavy attacks.

A possible explanation comes to mind in this connection. When infestations are at their height the available food supply per beetle is limited which causes a crowding of attacks. In such populations a vast brood may be started and partially develop and then, due to competition, be reduced to a lower level than the original brood. Referring again to Fig. (2) more than four times as many beetles emerged from the light attack than did from the heavy attack, although the bark area was considerably less in the case of the light attack. Mr. Keen has already pointed out that heavy populations of the pine

beetle do not necessarily produce heavy populations.

When an infestation is at low ebb in a stand containing numbers of susceptible trees, as is the case in the Modoc, there is an abundance of food for beetle. This results in the spreading out of attacks until each pair of beetles has approximately the area best suited for the development of their progeny. This condition existed on the Modoc during the season of 1933, as a direct result of the reduction of population by the freeze of 1932-33. One might go so far as to say that in susceptible stands, a severe reduction of the pine beetle serves to stimulate this species. The point is one which most certainly should be studied to its fullest extent.

SUMMARY

The present study supplements earlier observations on the life history of the western pine beetle on the Modoc and Sierra National Forests of California.

By sampling a series of brood trees in 1932 it was found that ~~three~~ four complete generations were developed on the Sierra during that year.

A similar set of observations in 1933 made it evident that only three complete generations were developed on the Sierra during that year.

The different number of generations in 1932 and 1933 on the Sierra was due to abnormally cold weather during the spring of 1933, which caused emergence of the overwintering generation to be delayed a full month longer than normally.

Tree cages erected on brood trees in the Modoc during the summer of 1933 furnished data to show that two generations and a partial third were developed.

Climatic differences between the Modoc N.F. and the Sierra N.F. account for the difference in number of generations that developed on the two forests during 1933. Severe winters and short growing season characterize the Modoc while mild winters and relatively long growing seasons prevail on the Sierra. Normally three complete generations develop on the Sierra while only two are completed on the Modoc.

During the winter season on the Sierra small larvae tend to develop intermittently during warm periods until, when activity begins in the spring, practically all the pine beetle population is in the large larval stage. There are no open periods during the winter in northern California so that small larvae do not develop before spring.

Dendroctonus brevicomis does not overwinter in the pupal stage in the ponderosa pine stands of California.

A caging experiment conducted in 1933 on the Modoc yielded the following information:

1. Parent adult beetles emerged to the extent of 53.8 percent of the attacking population.

2. Parent adult emergence began when the progeny was about quarter grown, reached its peak when the larvae were half grown and ceased just prior to the time that new adults emerged.

3. Reemerged parent adults were capable of establishing a second brood which developed to maturity.

4. Progeny of attacking beetles was 3.2 times the original population.

A life history chart showing hypothetical pine beetle development during 1933 on the Modoc illustrates how it is possible for this insect to nearly fully recover during a single season following severe population reduction.

Fig.(1)
Introduction Cage (A)
Hackamore, Modoc N.F.

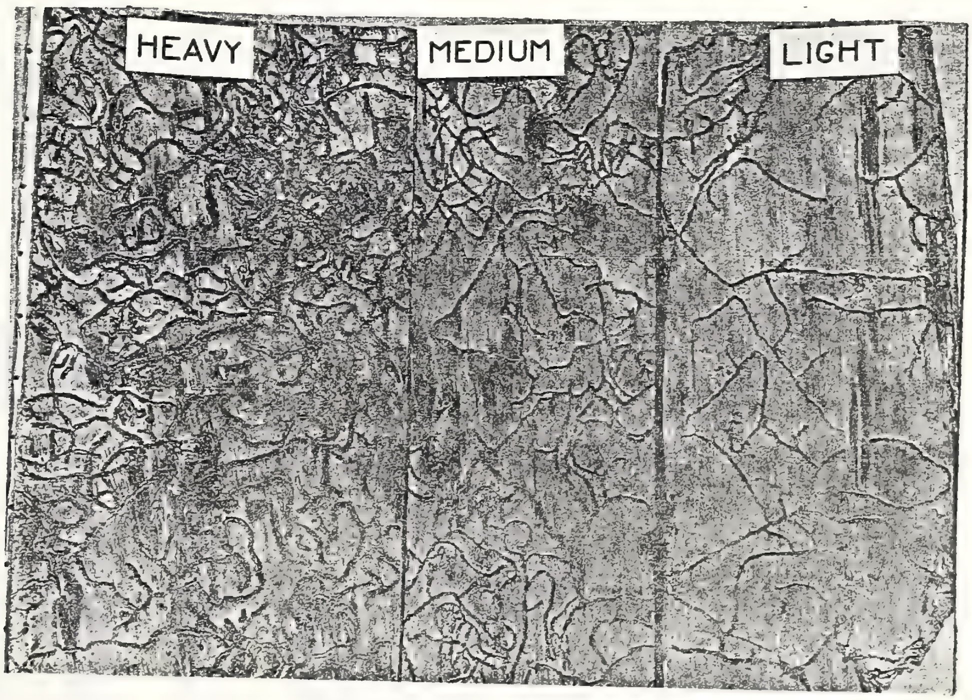
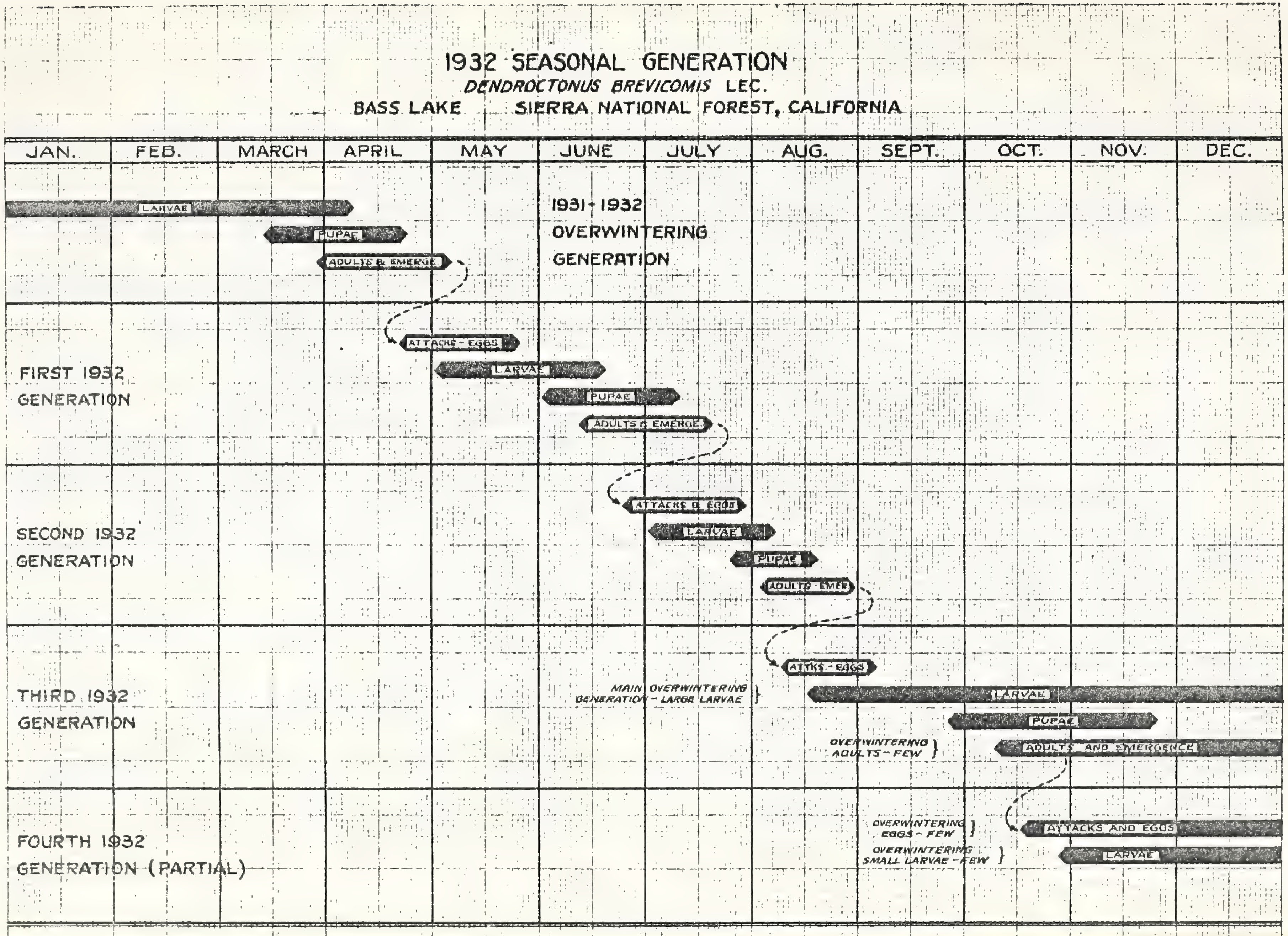
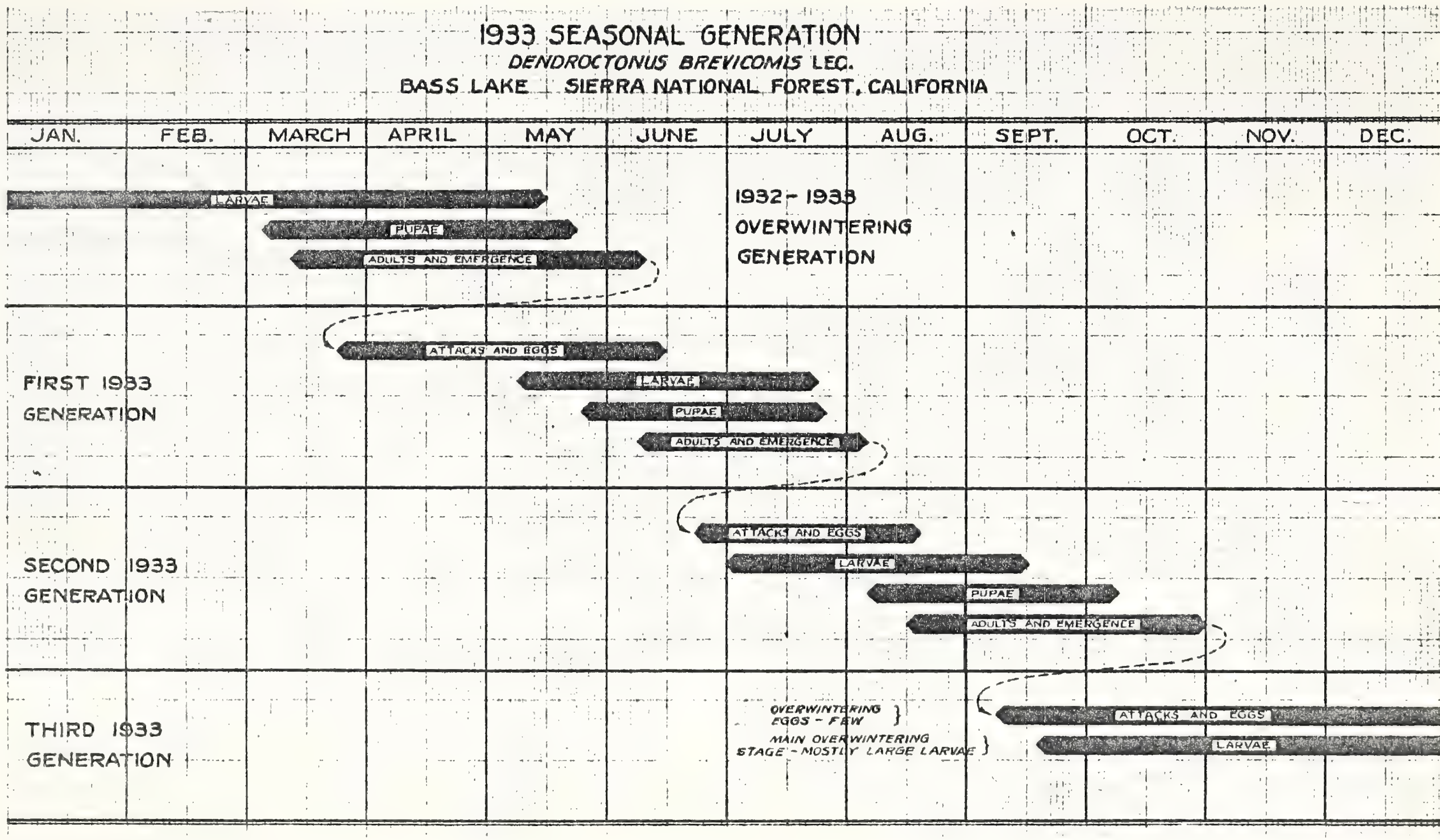
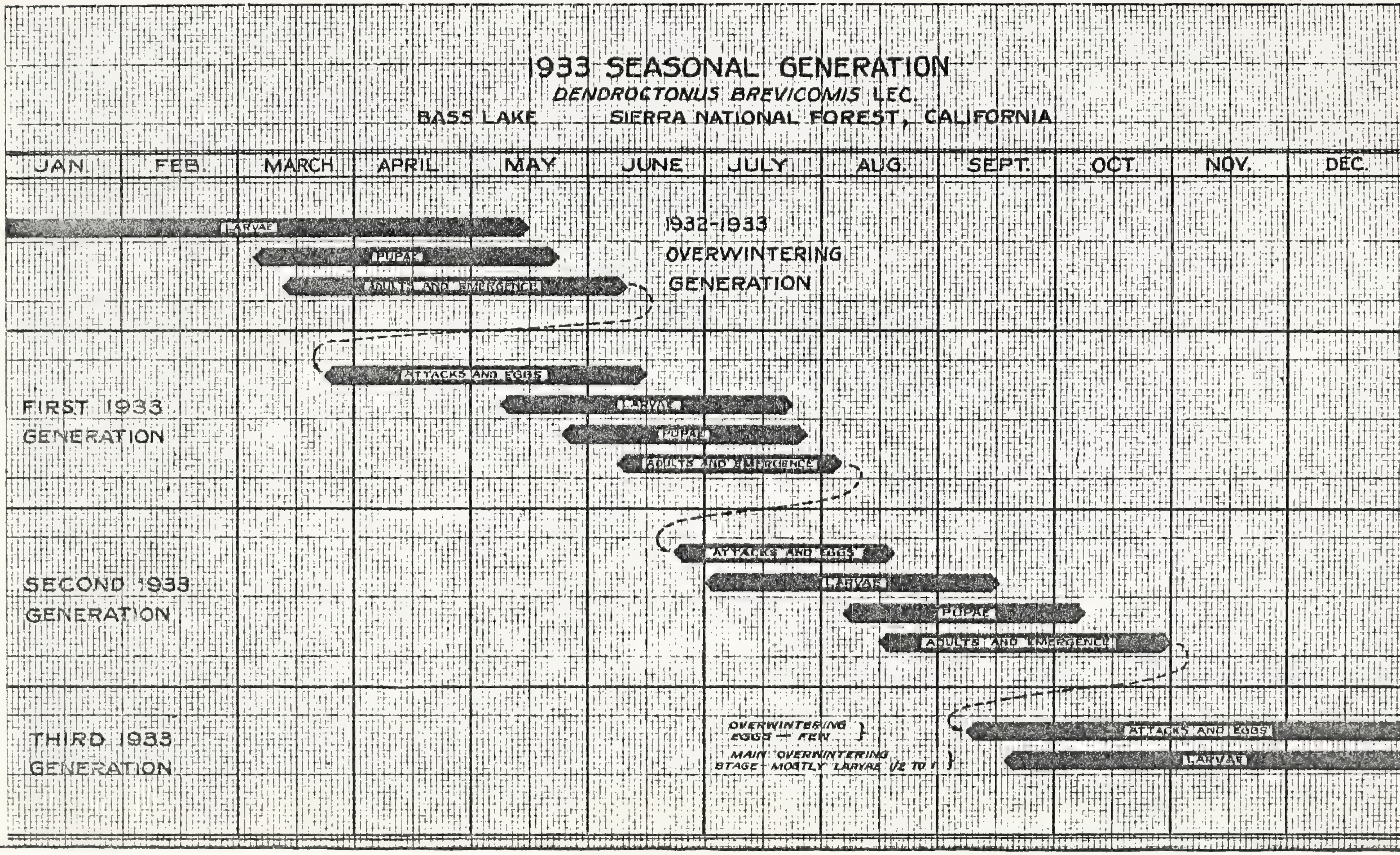
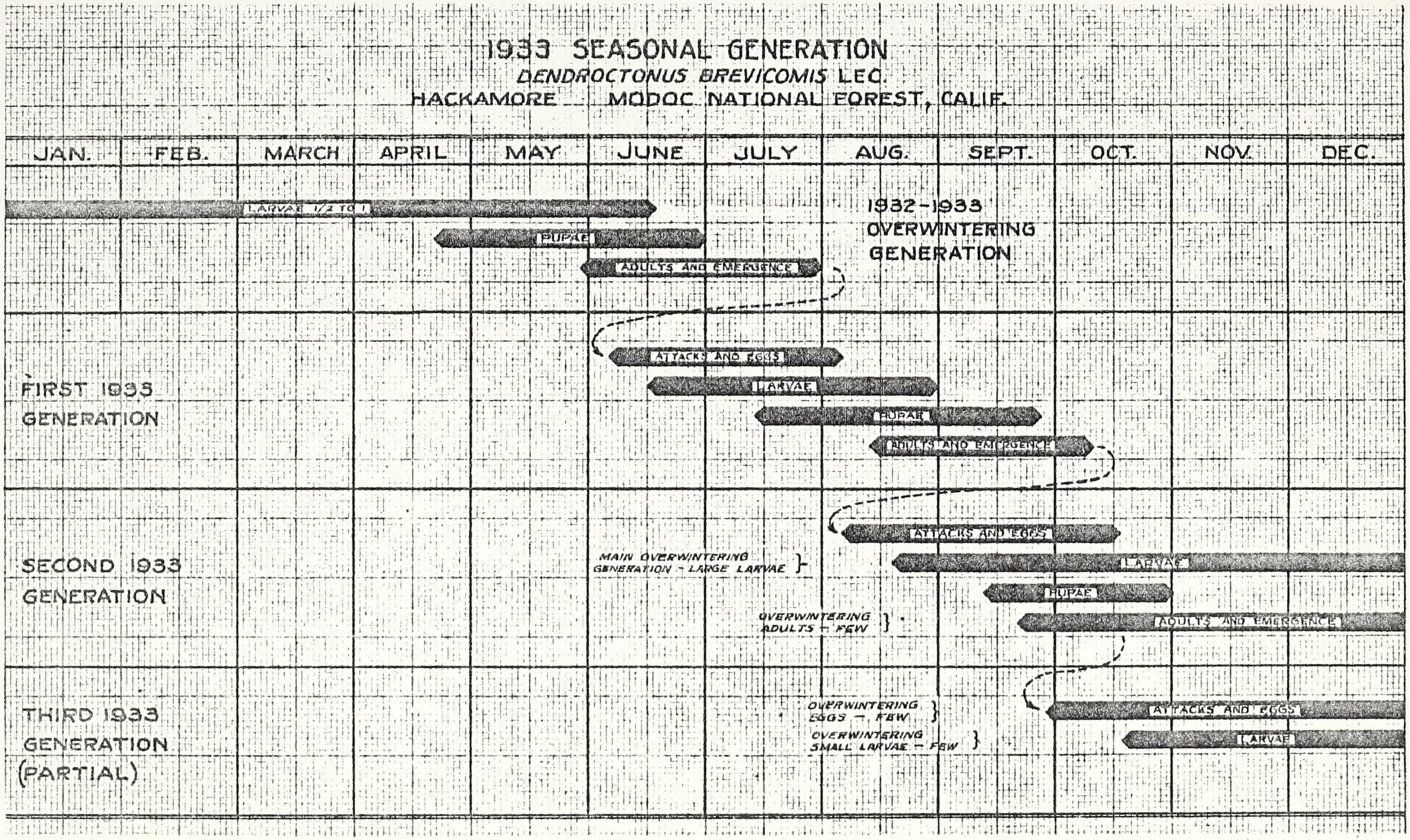


Fig. (2)
Bark samples showing comparative
density of Western Pine Beetle attack.


1932 SEASONAL GENERATION
DENDROCTONUS BREVICOMIS LEC.
BASS LAKE SIERRA NATIONAL FOREST, CALIFORNIA
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
LARVAE
PUPAE
ADULTS & EMERGE.
1931-1932
OVERWINTERING
GENERATION
FIRST 1932
GENERATION
ATTACKS - EGGS
LARVAE
PUPAE
ADULTS & EMERGE.
SECOND 1932
GENERATION
ATTACKS & EGGS
LARVAE
PUPAE
THIRD 1932
GENERATION
ATTKS - EGGS
MAIN OVERWINTERING
GENERATION - LARGE LARVAE
LARVAE
PUPAE
OVERWINTERING
ADULTS - FEW
ADULTS AND EMERGENCE
FOURTH 1932
GENERATION (PARTIAL)
OVERWINTERING
EGGS - FEW
ATTACKS AND EGGS
OVERWINTERING
SMALL LARVAE - FEW
LARVAE


1933 SEASONAL GENERATION
DENDROCTONUS BREVICOMIS LEC.
BASS LAKE SIERRA NATIONAL FOREST, CALIFORNIA
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
LARVAE
PUPAE
ADULTS AND EMERGENCE
1932 - 1933
OVERWINTERING
GENERATION
FIRST 1933
GENERATION
ATTACKS AND EGGS
LARVAE
PUPAE
ADULTS AND EMERGENCE
SECOND 1933
GENERATION
ATTACKS AND EGGS
LARVAE
PUPAE
ADULTS AND EMERGENCE
THIRD 1933
GENERATION
OVERWINTERING EGGS - FEW
MAIN OVERWINTERING STAGE - MOSTLY LARGE LARVAE
ATTACKS AND EGGS
LARVAE


1933 SEASONAL GENERATION
DENDROCTONUS BREVICOMIS LEC.
BASS LAKE SIERRA NATIONAL FOREST, CALIFORNIA
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
LARVAE
PUPAE
ADULTS AND EMERGENCE
1932-1933
OVERWINTERING
GENERATION
ATTACKS AND EGGS
LARVAE
PUPAE
ADULTS AND EMERGENCE
FIRST 1933
GENERATION
ATTACKS AND EGGS
LARVAE
PUPAE
ADULTS AND EMERGENCE
SECOND 1933
GENERATION
OVERWINTERING
EGGS — FEW
MAIN OVERWINTERING
STAGE – MOSTLY LARVAE 1/2 TO 1
ATTACKS AND EGGS
LARVAE
THIRD 1933
GENERATION


1933 SEASONAL GENERATION
DENDROCTONUS BREVICOMIS LEC.
HACKAMORE MODOC NATIONAL FOREST, CALIF.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
LARVAE 1/2 TO 1
PUPAE
ADULTS AND EMERGENCE
1932-1933
OVERWINTERING
GENERATION
ATTACKS AND EGGS
LARVAE
PUPAE
ADULTS AND EMERGENCE
FIRST 1933
GENERATION
ATTACKS AND EGGS
MAIN OVERWINTERING
GENERATION - LARGE LARVAE
LARVAE
SECOND 1933
GENERATION
PUPAE
OVERWINTERING
ADULTS - FEW
ADULTS AND EMERGENCE
THIRD 1933
GENERATION
(PARTIAL)
OVERWINTERING
EGGS - FEW
OVERWINTERING
SMALL LARVAE - FEW
ATTACKS AND EGGS
LARVAE